Monitoring Lakshadweep's Coral Reefs
Potentials and Pitfalls

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rohan arthur

Centre for Ecological Research and Conservation
3076/5, 4th Cross, Gokulam Park, Mysore 570 002, INDIA.
Ph: (+91) 821 510335 e-mail:arthur@ncf-india.org

INTRODUCTION

With the continuing loss of global biodiversity in the face of unchecked human development, conservation seems to be a largely pointless exercise in documenting extinction. Nowhere does this seem to be truer today than in the world's coral reefs. Today a spate of disturbances, natural and man-made threatens the fate of the reefs across the tropics (Bryant et al 1997, Wilkinson 1998), and there is an urgent need for rational ecological management and active conservation of reef areas. In India, more fundamental bridges need to be crossed before we can tackle the formidable challenge of reef management in disturbed environments. Almost no ecological research has been conducted on Indian reefs, and we have a scant understanding of the processes that affect its functioning (Bakus, 1994). Addressing these needs is not easy, and will probably need much longer than the needs of reef conservation will allow. While this happens it is important to have some handle on the trends operating in Indian coral reefs, to direct the hand of management, and alert ecological researchers to problems that may require more detailed study.

This survey was conducted to examine the feasibility of setting up a monitoring programme for the Lakshadweep Islands employing local youth and other committed individuals from the islands. It attempted a preliminary training of these volunteers in a range of monitoring techniques. The purpose was not to collect data that could be used as a baseline for monitoring, but to be an essential first-step in investigating possible obstacles involved in setting up a programme of this type, and determining the potential for setting up a functional, self-sustaining monitoring programme for the islands.

This report outlines in brief the major perceived threats to coral reef health, and makes a case for research and monitoring of reefs in India. After an introduction to the Lakshadweep Islands, it reports on the feasibility of setting up a monitoring programme there, and makes recommendations on the strategy to be employed in designing a programme that is most likely to succeed in Lakshadweep.

THREATS TO CORAL REEFS

Though coral reefs constitute a very small portion of the world's oceans, they are among the most phyletically diverse ecosystems we have. Distributed more or less pan-tropically between Cancer and Capricorn, coral reefs are highly specialised habitats that flourish in a narrow band of temperature, salinity and light levels. Except for a few oceanic reefs that grow on submerged volcanoes, coral reefs grow along the coasts of continents and islands, to a maximum depth of 60-70m, depending on light availability (Done et al. 1996)

The global distribution of coral reefs is, perhaps, an unfortunate one from the standpoint of ecological conservation, for they are most diverse in the most underdeveloped regions of the world, and though their contribution to global fisheries is negligible (Longhurst and Pauly, 1987), they are still a vital sustenance resource for a large population of people in these regions (Russ and Alcala, 1989). It is scarcely surprising then that most of the major threats to coral reefs today are direct or indirect consequences of human use and abuse.

Sedimentation: Among the biggest threats to reefs of the world appears to be not related to direct use of the reef at all, but the more insidious problem of sedimentation (Rajasuriya et al. 1995, Richmond 1993). Heavy development and beach erosion along the coast, mangrove and forest loss, leads to a weakening of the coastline, and causes in its wake a heavy runoff of sediment from the land to the sea. Much of this sediment is trapped by the reef and stifles the living coral beyond its natural ability to get rid of such particulate matter. Sedimentation has immediate and long-term effects on the health of reef ecosystems, and is one of the most difficult problems for reef conservation today.

Fishing: Overfishing of reefs is also a major factor in reef decline. Few studies have been done to examine carrying capacities of reefs, but much circumstantial evidence exists that reefs do not respond well to heavy fishing. For example, in the reefs of Kenya, with a fisher density of around 10/km stretch of coastline, with an offtake of about 4 kg of fish/fisher/day, the reefs showed detrimental impacts with a cascading effect to every ecosystem level when compared with reefs protected from fishing (McClanahan and Arthur *in press*, McClanahan and Kaunda-Arara 1995,). Fishing serves to remove predatory fish and important keystone species from the coral reef, which increase the abundance of sea urchins. Urchin explosions result in a

decline in coral cover and can lead to a phase shift of the reef community from a coral dominated to an algal dominated community, with consequences throughout the trophic chain (Done et al. 1996, Hughes et al. 1987). It is encouraging to note however, that reefs can recover from these changes with effective and innovative management, in a remarkably short time (McClanahan and Kaunda-Arara 1995).

Acanthaster outbreaks: Outbreaks of the corallivorous asteroid *Acanthaster planci*, the crown-of-thorns starfish (COTS), are also a major threat to reefs around the world. The reasons for the outbreaks of *Acanthaster planci* have not been conclusively investigated, but their populations seem to be correlated with nutrient enrichment caused by effluent discharge near reefs. Another reason often extended to explain the COTS phenomenon is the removal from the reef of their natural predators, the Triton shell for the ornamental trade. However it is unlikely that the naturally occurring populations of Triton in unexploited reefs could have a significant impact on COTS populations (Lassig et al. 1995). COTS can eat through reefs at an astonishingly rapid rate, and affect the fast-growing *Acropora's* most severely. They follow a boom-and-bust population cycle where they are abundant, and pose a serious problem for reef management.

Mass Bleaching, Cyclones, and other Disturbances: Several other natural factors affect coral reefs. Following ocean warming as a result of the El Niño Southern Oscillations (ENSO), coral often get rid of their symbiotic zooxanthallae, in a physiological stress reaction called bleaching. Under this condition of lowered resistance, the coral is made much more susceptible to other stresses, and is often killed by sedimentation, pollution, or sustained high temperatures (Brown, 1997). The ENSO of 1997-98 caused the most severe changes in sea surface temperatures (SSTs) since records were kept, and mass bleaching of corals was reported in reefs across the world. Post bleaching mortality was variable from region to region, mostly in conjunction with the level of anthropogenic disturbance, severity and duration of anomalous SST temperatures, and other regional factors. Previous research on mass-bleaching events indicates that coral reefs can often take several years if not decades to return to a semblance of their 'original' ecosystem state. Reefs are ecosystems highly susceptible to disturbances. Disturbance plays a very important role in the structuring of the system (Connell et al. 1997) and could help explain the high diversities seen in reef. The influence of cyclones, storms, reduced salinity events, global warming and other such natural events has received much attention in the literature (Hughes and Connell, 1999, Salvat 1987, Wilkinson and Buddemeier 1994).

Research and Monitoring for Coral Reef Conservation in India

India is not abundantly provided with coral reef habitat. On the mainland, Indian reefs are located in the Gulf of Kutch, in scattered locations along the West Coast of the country, and in the Gulf of Mannar and Palk Strait. Most of these reefs are either small patchy reefs of small conservation potential or significance, or else heavily threatened from a host of anthropogenic activities (Wafar 1986). The reefs of the Andaman and Nicobar Islands, and the Lakshadweeps however are reefs that still harbour rich diversities and present the best opportunities for reef conservation.

Conservation and management are built on watery foundations unless they are founded on reliable information. Vital aspects of information that are essential to the conservation process are knowing the components of the system, how these components interact with each other, and the trends evident in the system. The first of these concerns can be met with taxonomic studies, species listings, abundance estimations and other descriptive techniques. Figuring out how these components interact is a more involved process that can correctly be answered with rigorous population, community and ecosystem level studies. Resolving trends in the status of the system can be addressed only by sustained monitoring of the ecological components and processes that make up the system.

Thus far Indian reefs have received little scientific attention (Bakus 1994). The scientists who have worked on coral reefs have tended to focus their attention on exploitation studies or taxonomic listings. Virtually no rigorous studies at the population or community level exist for any Indian reefs. One of the main reasons for this lacuna, in my opinion, is that the research paradigm for doing marine ecological studies does not exist within the existing marine research institutions in India. Changes are being made in the recent past with increasing attention being focussed on the importance of understanding the ecology of the reef by international organisations, but the response thus far has been less than encouraging. Marine ecology requires a specialised training and scientific understanding of its own, and it is unreasonable to expect this to be effected rapidly. It probably requires a re-education of marine researchers

and the development of a focussed marine ecology education programme in the country, and both of these do not appear to be realistic goals for the near future.

Yet, reefs continue to be degraded. If current reports are to be believed (Hoegh-Guldberg 1999, Wilkinson 1998), reefs around the world are facing their worst catastrophe ever, and will probably not survive the next thirty years without substantial human intervention in their conservation. Whatever the demerits of these doomsday scenarios, it is clear that if we are to wait for laggard science in India to develop the essential resources with which to examine the reef at ecologically meaningful levels, we may well not have functioning reefs to examine, and we will, indeed, be reduced to documenting extinction yet again. It is important to devise, in this situation a workable set of tools in order to get a reasonable handle on the trends and functioning of the reef, so that we can have adequate warning when major changes in reef health take place, for remedial measures to be sought.

It is here that monitoring has the most potential to work. Monitoring is an attractive tool for intelligent reef management. It does not need an extended lag time of learning before ecosystem monitors can begin work in the field. It can serve to provide information to about ecosystem functioning at several temporal and spatial scales, and can direct attention to areas where more detailed inquiry may be needed.

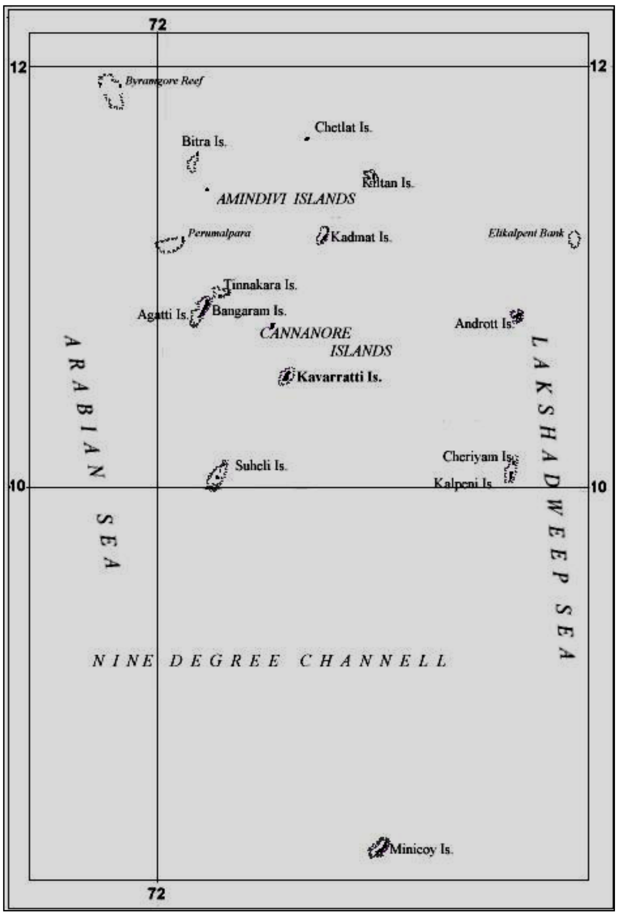
THE LAKSHADWEEP ISLANDS

The Lakshadweep Islands are a group of 12 atolls in the Arabian Sea, western Indian Ocean, off the west coast of India. Located between latitudes 8° N and 12° N, and longitudes 71° E and 74° E, it occupies a land area of 32 sq. km.

The reefs of the Lakshadweep are high diversity reefs, faunistically similar to the Maldivian reefs. The archipelago is an important biogeographic link between the southeast asian reef region and the East African coast.

Ten of the 27 islands that comprise the Lakshadweep are inhabited. Population density on inhabited islands is high, with a total estimated population of 60,000 people. Islam is the dominant religion, with 93% of the population, practising Muslims, and except for the island of Minicoy, the islanders share a similar ethnicity and language with the people of Kerala, in

south India. The inhabitants of Minicoy, at the southernmost tip of the chain, speak Mahl, and are ethnically related to the nearby Maldivians. The chief occupations of the Lakshadweepans are coconut cultivation and tuna fishing. Coconuts are cultivated for copra, coir and other related products which are processed and sold in mainland India. Tuna is either tinned or dried for mainland consumption; fresh meat is consumed locally, and is the primary meat source during the fair season. Tuna is by far the most lucrative fish for the Lakshadweepans and they hunt little else during the fair season. They employ a pole and line fishing method that requires live bait from the reef, in the form of small damsels, wrasses, and any other small fish that can be kept alive for several hours. Their dependence on the reef for fish increases during the monsoons when they cannot hunt the pelagic tuna. Shark fishing is also practised to a lesser degree. The islands rely heavily on the central Indian government for provisions and supplies, and it is a highly subsidised economy. Subsidies support everything from the tinning, transporting and marketing of island products, to electricity generation, communication, development and health.



The Lakshadweep Islands, India

METHODS TAUGHT AND NOTES ON THEIR USEFULNESS

A series of different methods was taught to volunteers from the islands of Minicoy and Kavaratti in the Lakshadweep Islands. Both islands have several active youth 'clubs' whose members involve themselves in social and ecologically oriented projects. They comprise environmentally aware, and enthusiastic youth from the island, who dedicate their free time to club activities. Most are self-employed fishermen, and have a fairly extensive knowledge of the reef. They work in close conjunction with the Department of Environment in their environmental activities, and a few of their members are rangers and wardens in the department. These organisations are remarkably well organised and disciplined, and offer a perfect existing resource base on which to structure a sustainable monitoring programme. The methods taught during this brief survey were aimed at looking at how easily volunteers took to the idea of quantitative sampling in the field, and what level of training would be required to get them to a level where they could adequately sample the reef more or less unsupervised. I started with relatively simple methods and progressed to more elaborate field techniques when the previous method seemed to be well understood.

Quantifying Benthic Substrate

Tracking changes to substrate composition is often the most important function of a monitoring programme. Coral and algae together make up the bulk of the biotic components of the substratum, and the interaction between these two groups often provides vital information on the status of the reef. Benthic quantification can reveal whether coral cover declines or increases over time, a pattern that may have important carry-on effects on the rest of the reef community. Similarly, it can provide information on the status of algal turfs and macroalgae on the reef, that may serve as important indicators of reef decline or recovery.

Line Transects: The Line Intercept Transect (LIT) is the most widely used technique for benthic monitoring of coral reefs (English et al. 1997). It consists of a rope or transect line laid out for a certain length along the substratum. All live components that are intercepted by the line are measured with a tape to the nearest cm. In addition, measurements of other non-biotic components such as sand and dead coral rock are also measured. We used a 30 m nylon weighted nylon rope for the LIT, and measured the components using tailor tape. In addition to intercept measurements, diagonal length measurements were also taken to obtain areas occupied by biotic components. The method required some training before the volunteers

could differentiate biotic components. Coral was classified according to their structural lifeform rather than genera (see English et al 1997). The volunteers easily understood this concept; they were all able to identify lifeforms within an hour of observation. The volunteers had a little more difficulty differentiating coralline algae from some encrusting coral.

The data obtained can be used in a variety of way to look at abundance and benthic composition or compare changes in composition over time, and can be modified to examine particular questions, for instance, the incidence of disease or bleaching events on the reef.

Sampling design with LITs: It is important to decide beforehand whether the monitoring programme should use fixed (permanent) transects that can be repeatedly sampled over time, or a stratified randomised design. It is currently fashionable to use permanent transects (Wilkinson 1998) in monitoring programmes because they require considerably less effort, and comparisons between times seems intuitively convincing. However, they pose several problems for statistical interpretation, and are based on the assumption that it is possible to accurately relocate the same one-dimensional sampled transect each time, something that is difficult to achieve in reality. Even small deviations from the sampled line can cause significant biases to the results obtained. Random transects have the disadvantage of requiring far more sampling effort to obtain equivalent data, but do not suffer from the assumptions of permanent transects, and can be interpreted with much more confidence. If the availability of trained volunteers is not likely to be a constraint, it is probably better to use random rather than permanent transects.

Point Centre Quarter: This method is considerably faster than the LIT but is best suited to collecting information on population densities of particular organisms. It does not provide information on overall benthic composition. A point is located every 5m along a transect, and the area around this centre is divided into four quadrants. The distance from the centre to the midpoint of the nearest individual in each quadrant is measured, and area measurements are recorded for these coral. This can be used to get accurate estimates of densities of particular coral lifeforms (Bakus 1990).

Though the volunteers easily grasped this method, it poses a few problems in the field. While it works well for many lifeforms of coral, branching coral in particular were difficult to measure using this method. This is because it is often very difficult establishing the limits of

the individual and, with a widely dispersed growth form, it often spreads out across several quadrants. This method may be a useful one for more detailed studies of particular genera or species of benthic organisms, but is probably not suitable for a monitoring programme.

Fish Community Quantification

Quantifying fish numbers and abundance is important for several reasons. Fish are often the most important resource directly harvested from the reef, and tracking their numbers provide important information on available stock. Reef fish are also very sensitive to changes in reef condition, and changes in richness, diversity and evenness of their communities are important indicators of ecosystem change.

Point Counts: The point count is the simplest and most intuitive method of quantifying fish species numbers, and volunteers did not need much coaching to learn the technique. It consists of choosing a random spot, and recording all species of fish seen within a fixed time of 5 minutes per count. Species were restricted to fish greater than 5 cm length. This method provides species richness information, but it can be modified to arrive at relative abundances. This is done over replicate counts by recording the minute in which each species was spotted. On average, the most abundant species will be seen earlier than rarer individuals.

Line Transects: Point counts normally provide information only on species richness of an area. Often it may be important to have information on fish abundance as well. The line transect is among the most widely used method for collecting this information (English et al. 1997). The transect comprises a 30m length of rope laid across the substratum. The observer swims at a distance of 2.5m from the transect, parallel to it. Counts are then made of fish species and number in a 5m belt, 2.5m on either side of the transect. The line transect took considerably longer to teach than the Point Count, but at the end of a few hours, most of the volunteers had mastered the technique.

Quantifying Fish – Cultural biases and ecological sampling: Quantifying fish presented an interesting set of problems for this survey. It was initially thought expedient to collect information on fish not at the species level, but at the level of the family, since it required less training to recognise common family types than to identify species. However, most of the volunteers were fishermen with a vast knowledge of fish, and identifying fish by species seemed to be a much simpler strategy for them. However, the Lakshadweepans, as every other fishing community, have their own unique classification for fish, and though it is often runs parallel to

the taxonomic classification we are used to, this is not always the case. Often male and female of the same species are identified by different names, as are different life history stages of the fish species. This is particularly true of the Labridae which undergo significant morphological shifts in appearance with age.

At the other end of the scale, several species that are taxonomically independent are given a collective name without differentiating between them. A striking example is the Chaetodontidae (Butterflyfish) which are all called '*khoka*' (in Minicoy) and '*fakikadisha*' (in Kavaratti) regardless of species, even though species differentiation is morphologically very clear in the butterflyfish.

Another important cultural bias that can easily be overlooked in the design of monitoring programmes is the sightability of fish species. It has long been known that all species are not equally sightable, but no studies have been done looking at cultural differences in sightability that may be quite separate from the morphological or behavioural characteristics of the species. The 5-minute fish count data collected shows the dangers of such biases. Replicate fish counts were done within the same reef patch by data collectors of different backgrounds – an experienced reef researcher (author), volunteers from the mainland, inexperienced with reef fish identification, and local volunteer fishermen. It is not surprising that mean species richness differed between observers. While the experienced researcher recorded 26.4 (± 3.3 SD), volunteers from the mainland recorded 13.2 (±1.6 SD) and local volunteers recorded 11.6 (± 2.7) species on average. Community similarity between counts done by the same recorder (Bray-Curtis Similarity Index) was high, varying between 79.4% (experienced observer) to 69.5% (inexperienced mainland observer), with local volunteers recording a similarity of 68.3% between transects. This is well within the natural variability observed for fish on reef patches. However, the similarity between observers was as low as 22.3%, indicating that there is a large inter-observer bias in the sampling. Examining the scant data collected from this survey indicates the possibility that cultural biases may be acting here. While the volunteers from the mainland recorded more of the more attractive and colourful fish species (Butterflies, Tangs, bright wrasses, etc), the local volunteers seemed to record more of the larger food fish species (parrots, goatfish, emperors) as well as the smaller species that are used as live bait for tuna fishing (mostly small damsels). If this cultural factor is indeed operating, it points to the need for more studies to be done to establish what exactly these may be, and how they may affect effective sampling of the reef.

Monitoring Indicators

Several techniques have been developed making use of particular aspects of behaviour and ecology of reef species that can be used as indicators of reef health. These are based on species that are very sensitive to particular aspects of reef decline.

Bioeroders: This method developed by Mike Risk (pers. comm.), makes use of bioeroders of coral as an indicator of nutrient levels in the lagoon. Nutrient increases stress coral significantly, though the effects may not always be noticeable immediately. This stressed coral often cannot resist invasion by a host of coral bioeroders such as boring worms and burrowing molluscs. The method involves sampling massive *Porites* individuals for bioeroders encountered within a small quadrat (25cm x 25cm). An old hanger can be bent to make a handy quadrat for this method. Volunteers picked up the technique very quickly (within 30mins), and it was possible to sample a large area, and get a large number of replicates using this method. Numbers of bioeroders counted serve as an indicator of nutrient loads, and can be compared with other sampling times to elucidate trends in pollution effects on the reef.

Butterflyfish species as indicators: Butterflyfish have been effectively used as indicators of coral health, and thus the health of the reef (Reese 1995). Many species are coral specialists, and defend coral resource territories. These species can be used as efficient indicators of trends in the ecosystem. The procedure consists of quantifying butterfly diversities in the reef using line transects, and measuring and monitoring individual butterfly territories from year to year. This method was abandoned when it became obvious that it was difficult for the island volunteers to distinguish one butterflyfish from another (a problem discussed above).

DESIGNING A MONITORING PROGRAMME:

Two essential criteria for any monitoring programme to be successful, is consistency of method and regularity of sampling. It is important in setting up a monitoring programme to ensure that the methods used are easily taught, reasonably accurate, and, given reasonable training, resistant from too much inter-observer bias. It is essential as well, to establish a reasonable temporal and spatial scale at which the monitoring is to be carried out. For long-term trends, an interval of a year between sampling times could be sufficient, though if seasonal changes are required, a quarterly schedule of monitoring is more appropriate. In the

event of large-scale events that may affect the reef, like the recent mass bleaching, a more intensive reef monitoring programme may be necessary to address the concerns of mass mortality and ecosystem change in these reefs.

As discussed, it is important to take into consideration cultural aspects when designing a monitoring programme. These are often ignored when importing monitoring programmes designed elsewhere, and may result in results that do not correctly address ecological reality.

The Lakshadweep volunteers are an enthusiastic and intelligent group of people and no great bridges of understanding need to be constructed before they understand concepts and techniques of monitoring. Guided by the Department of Environment, they could be moulded into a very useful monitoring unit, which could effectively carry out a monitoring programme for the islands. It might be necessary for an ecological researcher to make an annual visit to the reefs to standardize methods, train new volunteers and collate data collected each year.

Comparing monitoring and research:

It is often argued that as long there is some research being done in a particular region, there is no need to set up a monitoring programme since any major trends in the system will not go unnoticed. This is fallacious for several reasons. Research is not Monitoring, just as monitoring does not constitute research. Ecological research is based largely on a hypothetico-deductive approach, where questions are posed and data is collected to answer those questions. Monitoring on the other hand is based on a more neutral approach where trends are sought rather than questions asked. Thus there is a crucial difference in the conceptual approach to research and monitoring.

Most research programmes last only as long as notoriously fickle funding commitments hold out, and the interest of the individual researcher is sustained (typically the 3-4 years that a doctoral programme lasts). For coral reefs, where research projects have been carried out, they have generally been of much shorter duration than that. Another concern is that each individual researcher is interested in a particular aspect of the system and will use a suite of methods that are specifically honed to answer the questions posed. Comparing results of studies conducted using different methods, instruments and skills is dubious if not impossible.

Having said that, it is important to realise that datasets that result from extended monitoring can contribute a lot to ecological research. The need for such long-term datasets is axiomatic

in ecological research, demonstrated most effectively by Connell's 30-year on-going monitoring of coral quadrats in the Great Barrier Reef, where important lessons are being learnt about the role of disturbance and catastrophe in the structuring of coral communities (Connell, Hughes and Wallace 1997).

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